NASA Technical Paper 3657

The Evolution of the Posture Video Analysis Tool™ (PVAT)

Mihriban Whitmore and Andrea H. Berman
Lockheed Martin Engineering and Science Services
Houston, Texas

November 1996

Acknowledgments

This research was supported by contract number 0595-01390 from the National Aeronautics and Space Administration and conducted at the Lyndon B. Johnson Space Center in Houston, Texas. The authors wish to thank Jurine Adolf, Benjamin Bebernes, and Darlene Merced-Moore for their contributions during PVAT's evolution.

This publication is available from the NASA Center for AeroSpace Information, 800 Elkridge Landing Road, Linthicum Heights, MD 21090-2934, (301) 621-0390.

Contents

List of Tables and Figures

Acronyms

GPWS	general purpose workstation
GUI	graphical user interface
HFEL	Human Factors and Ergonomics Laboratory
PAT	Posture Analysis Tool
PVAR	Posture Video Analysis Tool
VAP	Video Analysis Protocol
VAT	Video Analysis Tool
VCR	videocassette recorder

The Evolution of the Posture Video Analysis Tool (PVAT)

1.0 Introduction

Working posture can be affected by the interaction of the operator with the design of the workplace environment and the tasks to be performed. Medical and ergonomic field studies suggest that awkward working postures may cause pains in muscle and connective tissues of tendons, joint capsules, and ligaments (Grandjean and Hunting, 1977). In support of space human factors research and applications, personnel at the National Aeronautics and Space Administration (NASA) Lyndon B. Johnson Space Center (JSC) defined a need to identify and further quantify the relationship among the activities, microgravity posture, and workstation design so that postural stress can be quantified and the specific causes of awkward posture identified. This information will help human factors researchers understand how humans live and work in space, and determine and sustain quality performance. These results could also benefit engineers in designing and/or modifying the environment or task for safety, comfort, and productivity. The primary means of obtaining microgravity working posture data has been through video downlinks and recordings, including supplementary inflight/ postflight questionnaires. Observational analysis of various Space Shuttle mission footage has revealed that important information (e.g., general postures, duration, frequency, design issues) can be extracted if a uniform methodology is devised.

Commercially available movement/posture evaluation systems require extensive data collection procedures, rigid camera calibrations, and referencing points. Strict control over the microgravity environment is not always possible due to limited personnel/ hardware resources and time constraints. Therefore, personnel at the JSC Human Factors and Ergonomics Laboratory (HFEL) developed the Posture Video Analysis Tool™ (PVAT) in response to a need for a low-cost, reliable method of collecting postural data from mission video shot under non-experimental conditions. In the past, traditional pencil-and-paper analysis of mission footage has revealed that important information such as posture, duration, frequency, and design issues could be extracted from the video with the use of a uniform methodology. PVAT (patent pending) provides the structured and controlled methodology needed to extract and classify working postures, even from videos not recorded specifically for experimental analysis. PVAT helps an analyst identify problem areas that contribute to poor posture and decreased human performance, which then aids the analyst in identifying design issues.

1.1 Tool Description

PVAT is an interactive, Macintosh menu- and button-driven, SuperCard®-based software prototype consisting of a setup and an analysis screen. Prior to the video analysis process, the analyst must first define the assessment parameters using the PVAT "Setup" screen (Fig. 1). PVAT has three analysis modes: body movement only (i.e., ankle flexion/extension), body activity only (i.e., squat, twist, reach), and body movement and activity combined (Figs. 2a, b, and c). The primary posture parameters to be selected for analysis in the Setup screen are: body position, body part, body movement and rating level, and/or activities. Once all of the entries have been completed, the analyst clicks on the "Initialize" button to begin the program, and the "Analysis" screen appears. Other features of the PVAT prototype include a terminology and definitions library; a brief set of animations illustrating selected posture classifications; on-line help; report printing capability; and basic data reduction summaries (i.e., frequency and duration of body movements and activities). Following the setup, the analyst may begin analyzing the selected video footage using PVAT. Each posture classification is stored and time-stamped automatically. Having completed the assessment process, the analyst can summarize the data in terms of posture classification frequency and overall duration.

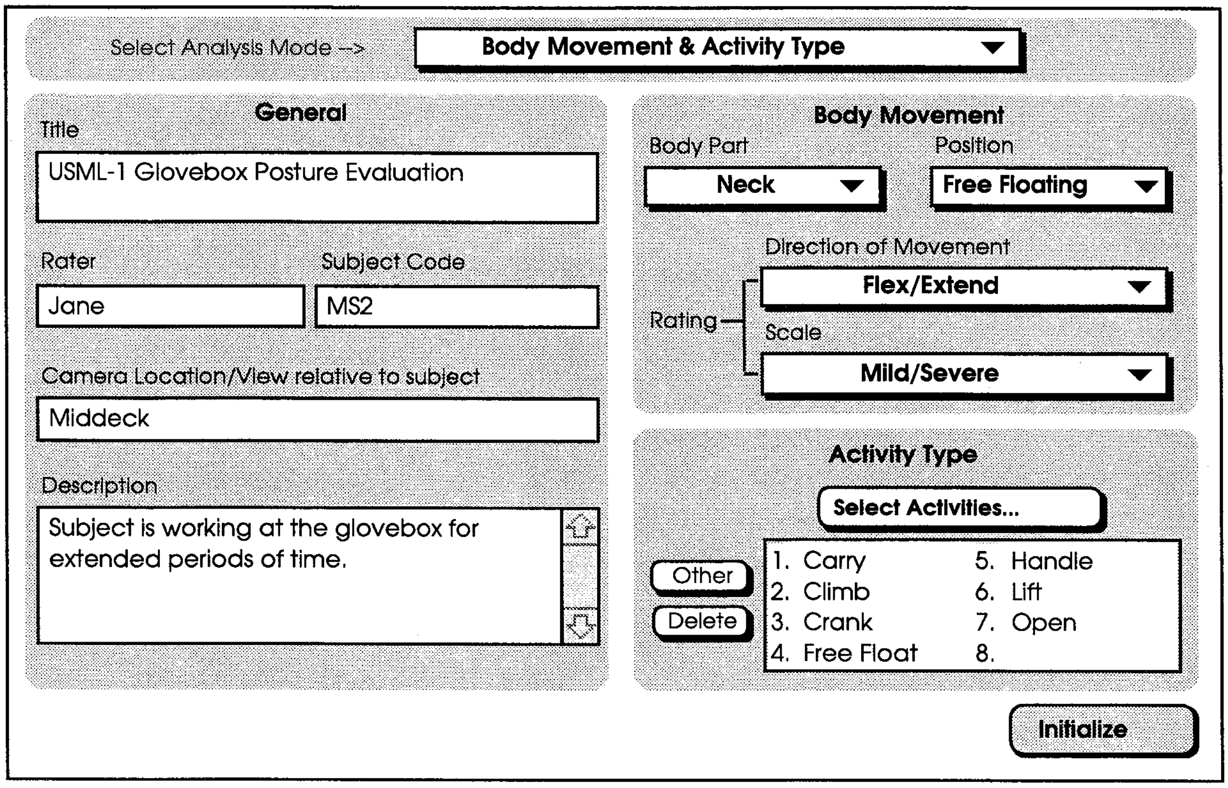

Figure 1. PVAT setup screen.

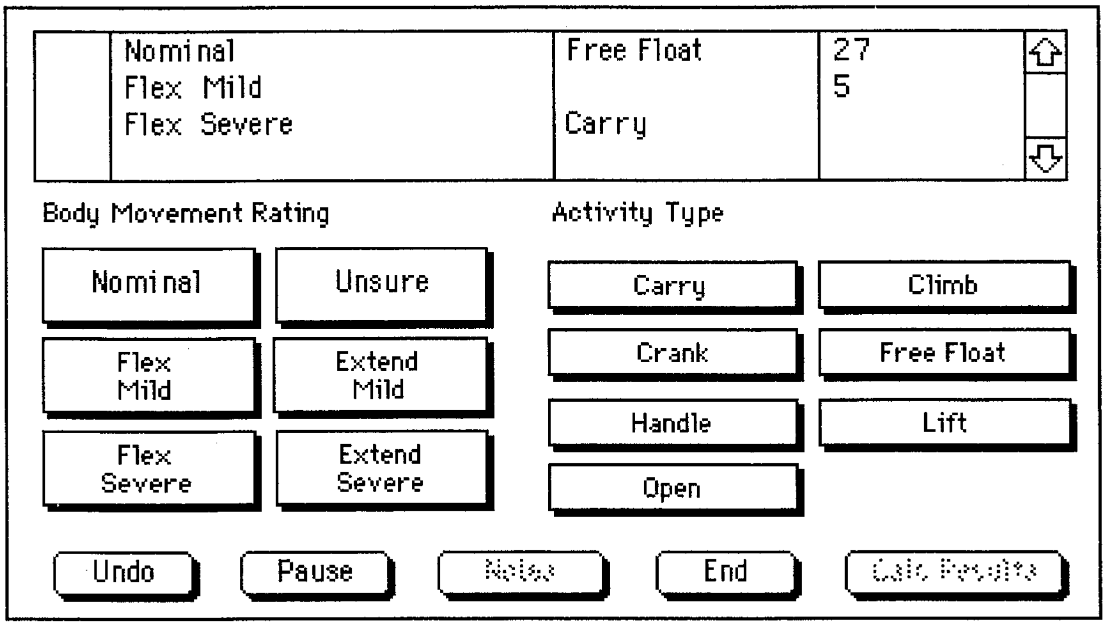

Figure 2a. PVAT analysis screen for "Body Movement and Activity Type" mode.

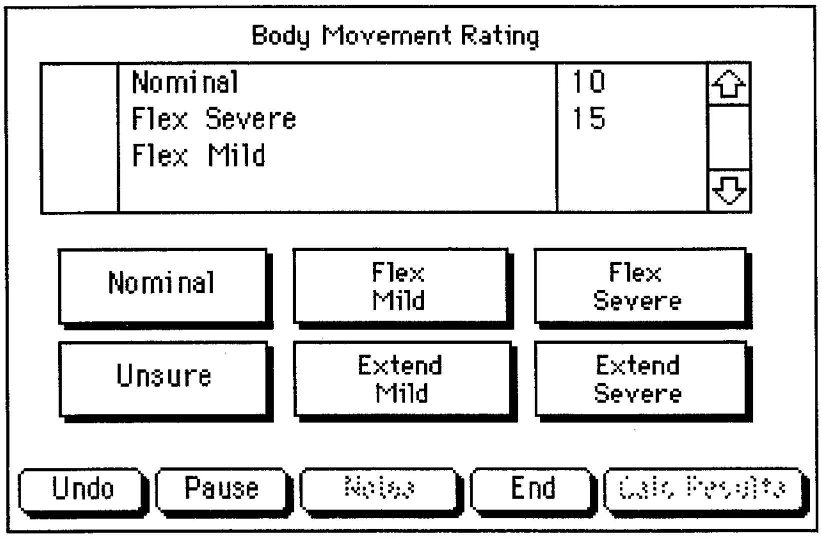

Figure 2b. PVAT analysis screen for "Body Movement Only" mode.

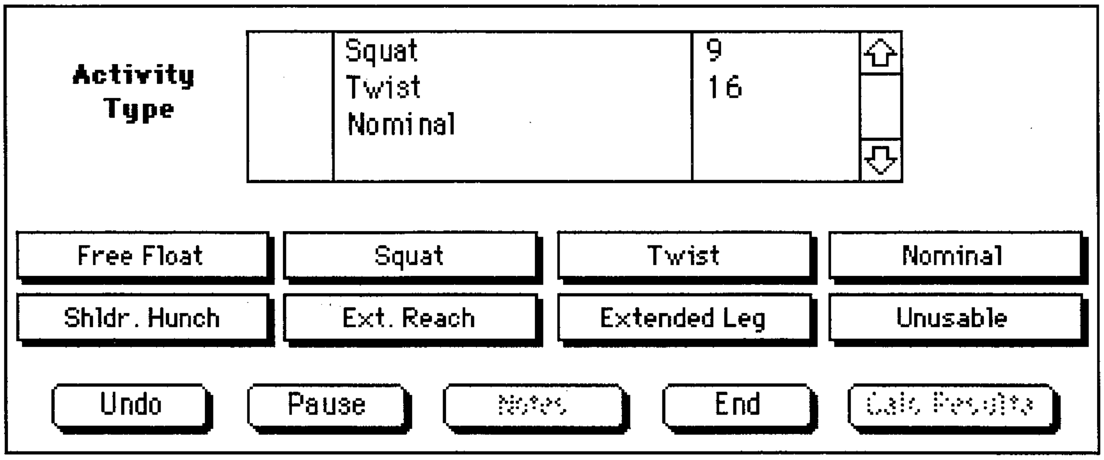

Figure 2c. PVAT analysis screen for "Activity Type Only" mode.

2.0 Usability Evaluation History

Since its creation, PVAT has undergone many phases of usability testing and still requires further evaluation to refine its graphical user interface (GUI) and to demonstrate its commercial application. The testing accomplished thus far has assisted the PVAT designers tremendously in refining the user interface with both subtle and sweeping changes.

2.1 Preliminary Design Evaluation Phase

During the first phase, evaluations centered around raters' comments rather than objective data collection. Raters were experienced human factors engineers and psychologists with experience in video analysis and user interface design. PVAT underwent four iterations in this phase—from a single-screen, pull-down menu application to the more complex setup/analysis screen concept that led to its current design.

2.1.1 Video Analysis Protocol (VAP)

PVAT's first iteration was referred to as VAP. VAP's interface was a single setup/analysis screen with icons that revealed pull-down menus (Appendix A, Fig. A-1). The subjective comments from the VAP design evaluation led to the separation of the setup and analysis screens, a restructure of the data output, and the need to change the pull-down menu concept (the raters found pull-down menu selection too time-consuming).

2.1.2 *Posture Analysis Tool (PAT)*

The VAP testing led to the dual-screen concept and the new name, PAT (Appendix A, Figs. A-2a and b). The design evaluation suggestions were to limit user selection options, to define more clearly the user requirements, and to optimize screen utilization.

2.1.3 *Video Analysis Tool (VAT)*

The third iteration, VAT, began the evolution toward PVAT as it exists currently. Making modifications only on the setup screen, the following changes were made:

- Automated user input
- Assigned command key functions
- Incorporated the user help function
- Improved screen utilization from the PAT iteration (Appendix A, Fig. A-3)

For the next iteration, raters commented that the "Posture Classification" input fields required better definition and that the command keys were not feasible in this type of application.

2.1.4 *Posture Video Analysis Tool (PVAT)*

The tool received its current name in this fourth design iteration and evaluation. In the setup screen, the following changes were made:

- Created subcategories for the Posture Classification fields for user input, for clarification purposes
- Incorporated scrolling fields to save real estate
- Modified the analysis screen
- Adopted a new rating scale input format (Appendix A, Figs. A-4a and b)

Raters were asked to comment on the setup and analysis screens separately. Comments on the setup screen included the need for a reevaluation by the designers of software-required inputs to reduce the number of inputs truly required of the user. Comments on the output screen included too much clutter, cumbersome rating scale input format, and user selection buttons that required reformatting.

2.2 Usability Testing Phase

The final preliminary design evaluation described in Section 2.1.4 yielded the first version of PVAT to undergo full-blown usability testing (Appendix A, Figs. A-5a and b). The modifications to the setup screen were twofold: input definition was improved through the use of labels, and the dual rating capability of both body movements and body activities was incorporated. The following changes were made to the analysis screen:

- Reduced screen clutter and size
- Incorporated discrete rating button format
- Restructured output format and layout
- Incorporated automatic user prompts

2.2.1 Initial Usability Testing

The first phase of full-blown usability testing had two objectives. First, user consistency was investigated. Secondly, the use of the tool as a means of postural analysis was objectively evaluated. These objectives had equal importance: If PVAT did not succeed in both these areas, a major redesign and change in design philosophy would be required.

2.2.1.1 User Consistency Study. Two raters were trained to use PVAT. The raters were trained to spot the predefined posture categories to be analyzed on the video, which was downlink of astronauts working at a glovebox during a Shuttle mission. Each rater reviewed two video segments from the mission twice. Their PVAT sessions were videotaped, and they both completed a questionnaire at the end of every session (Whitmore and McKay, 1994a).

Consistency both within and between subjects was investigated. For subject 1, the within subject difference for percentage time the video subject spent in each posture category ranged from 0.03% to 5.73% (with the exception of one posture category, where the difference was 11.4%). For subject 2, the within subject difference ranged from 0.01% to 5.11%.

The between subject differences for percentage time the video subject spent in each posture category during the first video segment ranged from 0.40% to 7.30% (with the exception of one category, where the difference was 11.12%). For the second video segment, the percentage differences ranged from 0.08% to 8.26% (Whitmore and McKay, 1994b).

2.2.1.2 Objective PVAT Usability Study. Once again, two raters were trained to use PVAT, and the raters were trained to spot the predefined posture categories to be analyzed on the video. For this study, the raters analyzed a video from a KC-135, zero-gravity flight ergonomic evaluation of the general purpose workstation (GPWS). The neck was targeted for this evaluation since it was the body part most affected by the GPWS design. The PVAT raters were instructed to classify the neck posture as *Nominal,* if the neck appeared to deviate 0-20° from a reference plane; *Mild flex/extend,* if the deviation was between 20-45°; and *Severe flex/extend,* if the deviation was greater than 45° (taken from Leonard and Keyserling, 1989).

Figure 3 shows a portion of the posture analysis results. "It is evident from this analysis that there were differences in neck flexion between the 95th percentile male and the 5th percentile female subjects. Males were found to have more severe neck flexion (12%) than females (1%). This was attributed to the design limitations of the GPWS where taller operators tend to bend and hover their upper body in order to look inside the glovebox. Data of this nature is needed to support design and operational recommendations from a human performance standpoint" (Whitmore, Merced-Moore, and Adam, 1993, p. 4).

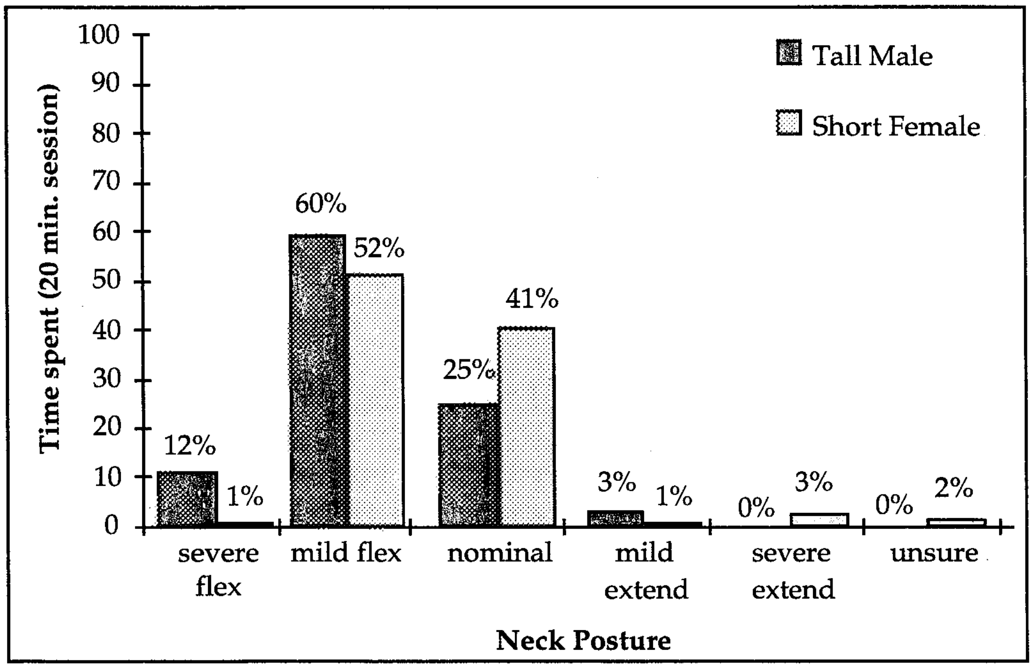

Figure 3. A portion of the objective results of the phase one usability testing.

Based on the results of this dual-objective usability testing, PVAT was determined to be a successful prototype tool for software-based posture analysis; it "...may indeed help to determine potential causes of restricted working postures" (Whitmore et al., 1993, p. 4). It was decided to proceed with further usability testing.

2.2.2 *Follow-up Usability Testing*

As part of the previous phase discussed in Section 2.2.1, the raters were also asked to critique the software. They suggested incorporation of the following changes (Whitmore et al., 1993):

- New button locations
- An automatic "save" prompt
- A modified screen layout
- A smaller output field
- Flagging of incorrect entries for deletion

These design suggestions were incorporated into the redesign of PVAT used in the second phase of usability testing (Figs. 1 and 2). Other modifications made for this phase of testing included the renaming of some buttons, the addition of a "Calculate Summary" option for a quick summary of the data, and the separation of the analysis screen into three modes: (1) Body Movement Only, (2) Activity Only, and (3) Body Movement and Activity. With these three modes, it became possible to analyze body movements only (i.e., ankle flexion/extension), body activity only (i.e., squat, twist, reach), or body movement and activity combined.

2.2.2.1 Method. This phase of testing most closely resembles the traditional, full-blown software usability testing widely used in all industries by human factors engineers and psychologists. The following usability questions were to be answered in this study:

(1) Is the software usable?

(2) How long does it take to complete an analysis of an 8-minute video segment?

Five subjects were trained on PVAT and on the body movements and activities to be rated. They each analyzed three 7-8-minute video segments from both KC-135 and Shuttle evaluations in random order, using all three analysis modes of this version of PVAT: Body Movement Only, Activity Only, and Body Movement and Activity combined. The pairing of video segment and PVAT analysis mode remained constant across subjects. All subjects completed a subjective questionnaire after the experiment that asked them to rate and to comment on the software interface (Whitmore and McKay, 1995).

The HFEL's usability testing facility was the site of this study. Three camera views were recorded: two camera views of the subject and one scanned view of the monitor. Subjects were encouraged to think aloud, and the test conductor monitored the sessions in the control room and assisted the subjects upon request (Whitmore and McKay, 1995).

2.2.2.2 Results. PVAT was found to be acceptable in terms of completing the full video analysis. A longer setup time for the Body Activity Only mode seemed to be possibly due to entering categories not included in the activity list (Figure 4). The length of the analysis phase was not significantly longer than the duration of the video segment for any of the analysis modes.

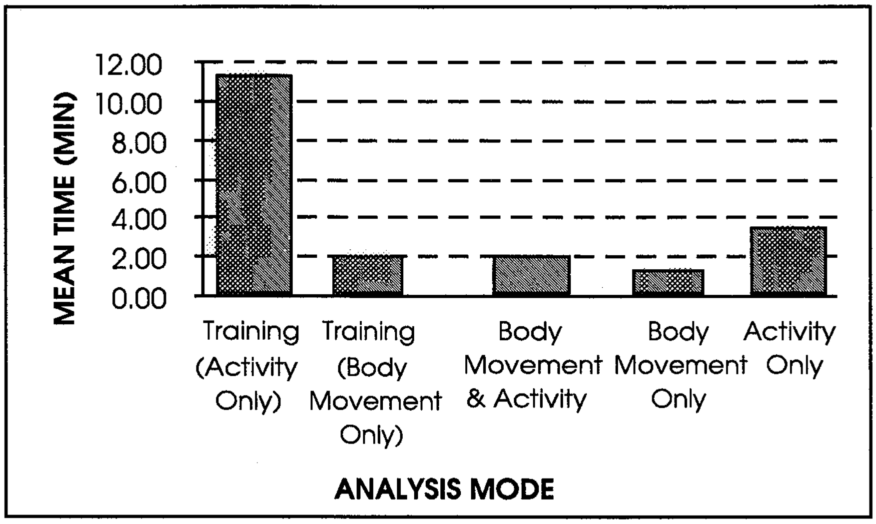

Figure 4. Task completion times for the setup phase of PVAT sessions.

The subjects rated the screen layout and procedure acceptable for both the setup and the analysis screens. The overall reaction to PVAT was positive. All subjects found it easy to learn, and four out of five subjects found it easy to use. All subjects stated that they would use it again.

The subjects required minor software assistance only during the training session. Some difficulty was reported in switching attention between the computer monitor and the videotape (Whitmore and McKay, 1995).

2.2.3 *Walkthrough Evaluation*

Part of the subjective questionnaire administered during the follow-up usability testing, discussed in Section 2.2.2, gave the subjects an opportunity to suggest modifications. For the setup screen, they suggested that modifications be made to the "Select Activities" dialogue, which allows the user to select from an internal list of body activities or to add other activities to the analysis. Suggested modifications to the analysis screen were to change the locations of some buttons and the sizes of others. However, no comments were made concerning the "Undo" button used to correct a mistake during the video analysis. Therefore, the current version (Figs. 1 and 2) was used in the most recent PVAT testing—a usability walkthrough evaluation.

During the testing discussed in Section 2.2.2, we had hoped that subjects would need to use the Undo function to correct errors made in analyzing the preselected video segments. However, the subjects rarely used the Undo function, therefore not enough data were obtained to determine its intuitiveness. This walkthrough allowed the HFEL to conduct an in-depth investigation into users' expectations when using PVAT's Undo function. Because there are two types of errors a PVAT user may correct with the Undo button, we expected that confusion would arise regarding how to correct each type of error. Table 1 outlines these two error types ("slips" and "mistakes") and the procedures to correct them (Berman and Whitmore, 1996).

TABLE 1

Types of Errors Corrected by "Undo" and Procedures to Correct Them

TYPE OF ERROR	DESCRIPTION	CORRECTION
"Slip"	Clicked mouse by accident and caused a Body Movement Rating to be entered.	Click "Undo"; Click previous Body Movement Rating chosen to continue time-tagging it.
"Mistake"	Clicked on wrong Body Movement Rating and need to replace it with the correct one.	Click "Undo"; Click correct Body Movement Rating to start time-tagging it.

2.2.3.1 Method. The walkthrough consisted of stepping 12 subjects through two tasks, each of which walked the subject through the steps necessary to correct a slip or a mistake. The tasks were presented on separate pages, and the task descriptions were accompanied by a still image of the analysis screen as well as space for the subject to write his/her response.

The level of instruction necessary to successfully accomplish the tasks was also investigated by presenting half the subjects with instructions which specifically spelled out the two different uses of the Undo button. The other half received generic instructions with a vague reference to the use of the Undo button.

2.2.3.2 Results. Figure 5 presents the results graphically. For the slip error, the level of instruction seemed to have a large effect on the number of correct responses. Approximately 83% (5 out of 6) of the subjects who received the generic instructions did not successfully complete the slip correction task, whereas 33% (2 out of 6) of those who received the specific instructions did not succeed. For the mistake case, level of instruction seemed to have much less of an effect on accuracy of response; 92% of the subject pool (11 out of 12) correctly performed the task related to mistakes.

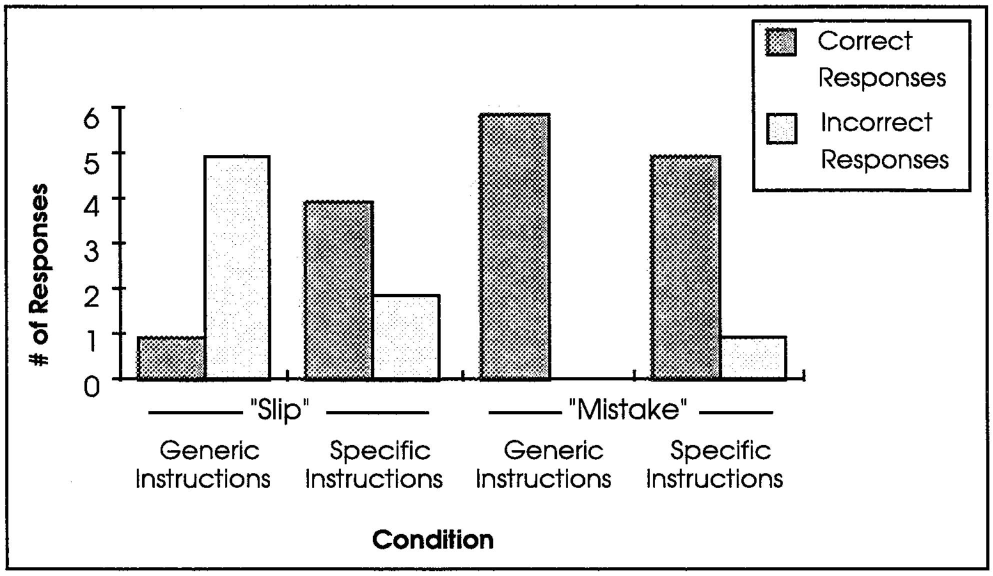

Figure 5. Subject responses graphed by condition.

The level of instruction played a large role in whether the subject chose the correct action for the slip task. Perhaps based on previous experience with GUIs, five of the six subjects provided with generic instructions expected that clicking on Undo would automatically return the software to its previous state (e.g., continue timing the previous entry). It was counter-intuitive to them that the user was required to reselect the previous category to exit the Undo function and continue the video analysis.

The current procedure for correcting a mistake is indeed intuitive to users with at least a basic level of understanding of GUIs. The current procedure for correcting a slip is not entirely intuitive, but increasing the level of instruction provided to the user did in fact improve task performance. A variety of design solutions is now under investigation and, in the interim, specific training in the corrective procedures will be stressed during user training.

3.0 Conclusions

Overall, PVAT appears to be a promising tool for use in gathering data non-intrusively in a microgravity environment. PVAT provides the initial step in identifying and quantifying "limiting microgravity postures" and related workstation design concerns. Furthermore, it may provide the analyst with supporting quantitative data to specify "adequate" microgravity postures or "safe" durations for certain microgravity postures perceived as potentially dangerous. It can contribute to various aspects of workplace design such as training, task allocations, procedural analysis, scheduling of timelines, and hardware usability evaluations. We also anticipate that PVAT will be applicable in a host of non-aerospace industries with little or no modification. Examples include medical operation rooms, contaminated areas, and control rooms.

3.1 Commercial Applications

Industries such as manufacturing plants, offices, laboratories, and service industries such as postal or food services typically require workers to maintain prolonged postures. The posture may involve sitting, standing, or both sitting and standing to perform the work. A person should not be restricted to a workplace in such a way that he or she cannot change posture during the work shift. If a worker can achieve an extended reach only by leaning, stretching, stooping or crouching, these postures may all produce fatigue for that worker.

In addition, some work environments may require the use of specialized equipment, such as computers, chemical hoods, or gloveboxes. This equipment may place constraints on the operator such as restricted arm movement or vision, which in turn may cause discomfort or fatigue and make the task awkward to perform.

PVAT can assist engineers in designing both the tasks and the equipment to be used. PVAT could also assist in evaluating existing workplace environments to determine problem areas resulting from the posture demands of the task.

Many health professionals are concerned with the posture an individual may assume. Occupational and physical therapists and nursing professionals are aware that prolonged or awkward posture may fatigue and/or result in physical complications for a patient. These professionals could use PVAT to study postures that patients use to perform specified tasks at home or at work. It may also be used to assess the effectiveness of various sedentary positions for recovering patients. Alternative postures could be identified, thereby allowing recovery for the patient with some postural flexibility.

Such evaluations may also result in the identification of aids to assist the individual in performing tasks or attaining sedentary comfort. Examples of useful aids include specially designed chairs, foot or back supports, or tools for performing a task.

3.2 Recommendations for Future Work

Advanced features such as an animated posture classification glossary and automated control of the videocassette recorder (VCR) within PVAT should be incorporated. The Undo function should be reworked and the walkthrough subjects' design suggestions should be incorporated. In addition, field testing should be conducted to investigate PVAT's applicability to industry.

4.0 References

Berman, A. H. and Whitmore, M. (1996). A usability walkthrough of the Posture Video Analysis Tool. In Proceedings of the Silicon Valley Ergonomics Conference. San Jose, CA: Silicon Valley Ergonomics Institute.

Grandjean, E. and Hunting, W. (1977). Ergonomics of posture - Review of various problems of standing and sitting posture, Applied Ergonomics, 8(3), 135-140.

Leonard, J. and Keyserling, W. M. (1989). A method to evaluate neck and lower extremity postures using simulated real time analysis. In Mital, A. (Ed.), Advances in Industrial Ergonomics and Safety I. Great Britain: Taylor and Francis.

Whitmore, M. and McKay, T.D. (1994a).. PVAT: Development of a video analysis tool. In Human Factors in Computing Systems: CHI '94 Conference Companion. New York, NY: Association for Computing Machinery.

Whitmore, M. and McKay, T.D. (1994b). Use of Video Analysis System for Working Posture Evaluations. Paper presented at the Dual-Use Space Technology Transfer Conference.

Whitmore, M. and McKay, T.D. (1995). PVAT: Usability testing of posture video analysis tool. In Human Factors in Computing Systems: CHI '95 Conference Companion. New York, NY: Association for Computing Machinery.

Whitmore, M., Merced-Moore, D. and Adam, S. C. (1993). PVAT - A video analysis tool for microgravity posture evaluation. In Proceedings of the Human Factors Society 37th Annual Meeting. Santa Monica, CA: Human Factors and Ergonomic Society.

APPENDIX A

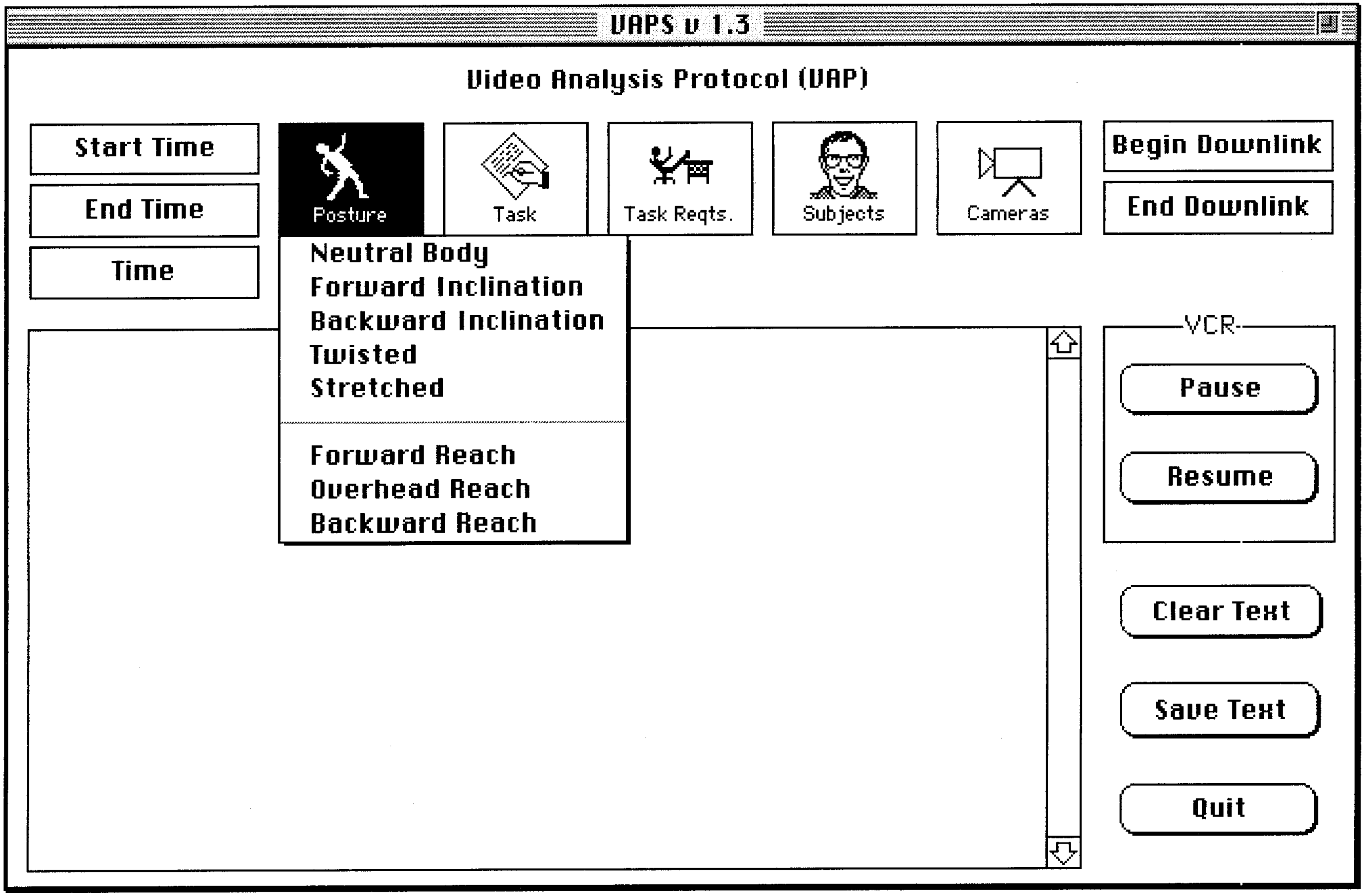

Figure A-1. The Video Analysis Protocol (VAP).

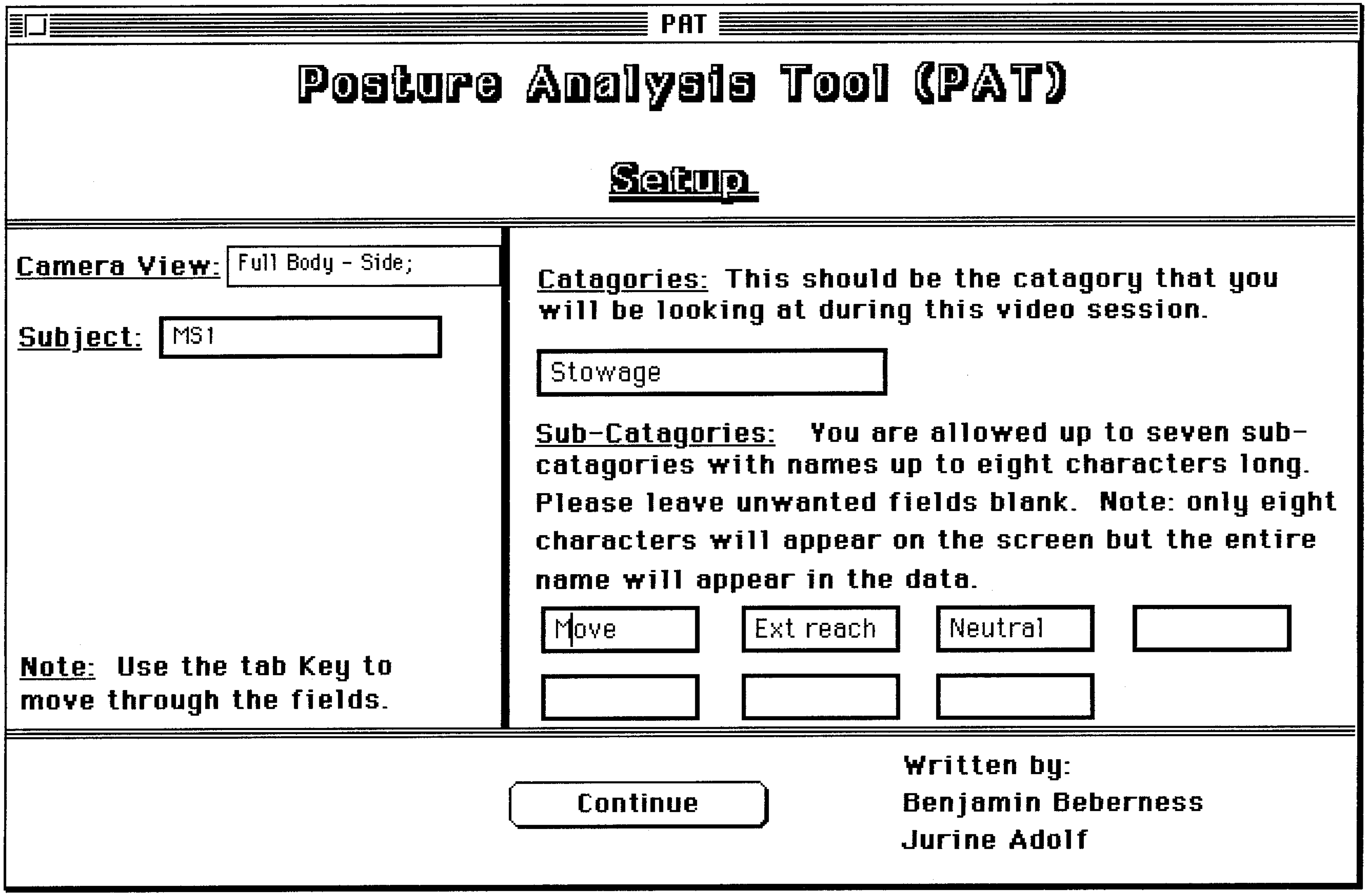

Figure A-2a. The Posture Analysis Tool (PAT) setup screen.

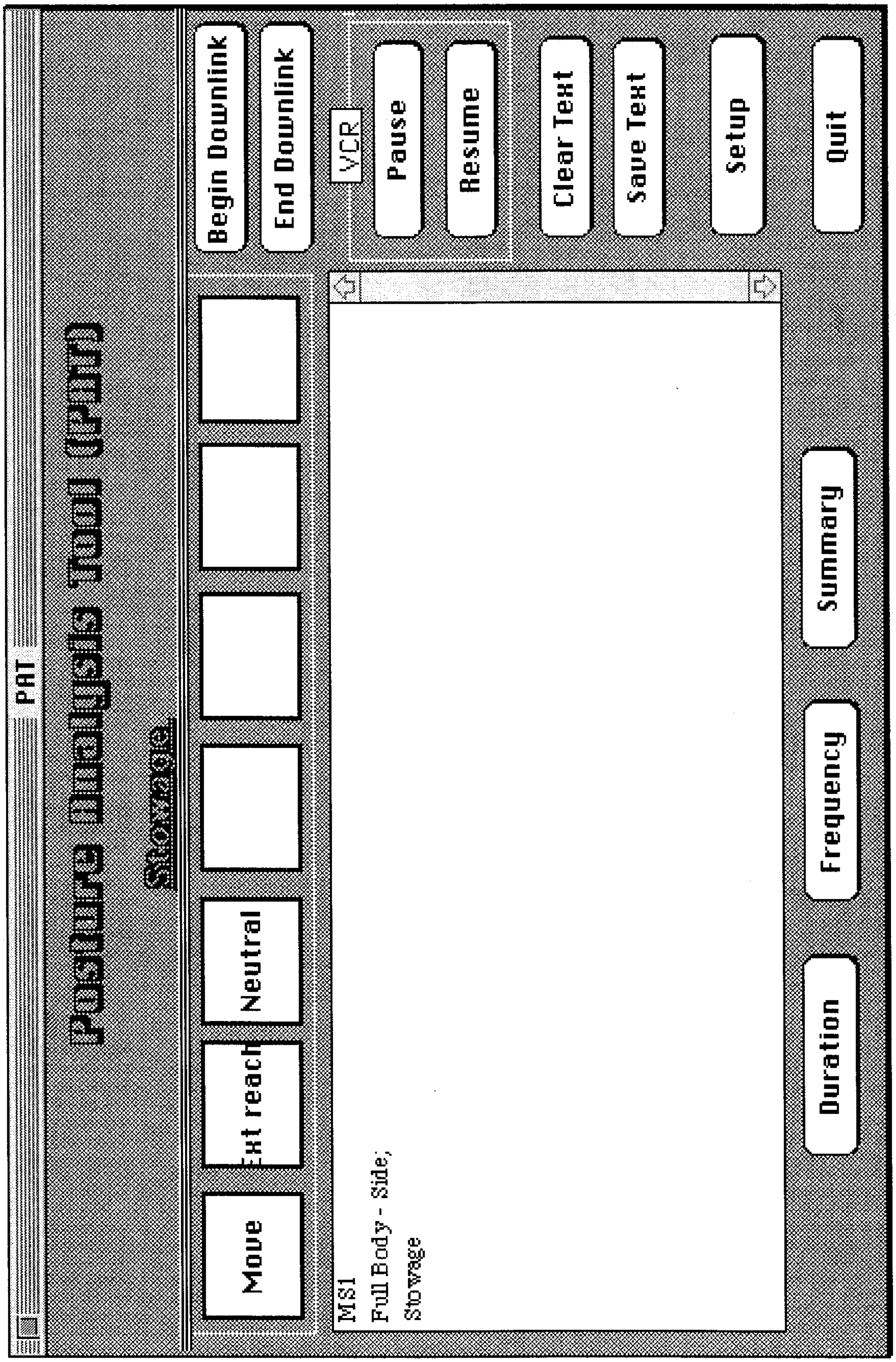

Figure A-2b. The Posture Analysis Tool (PAT) analysis screen.

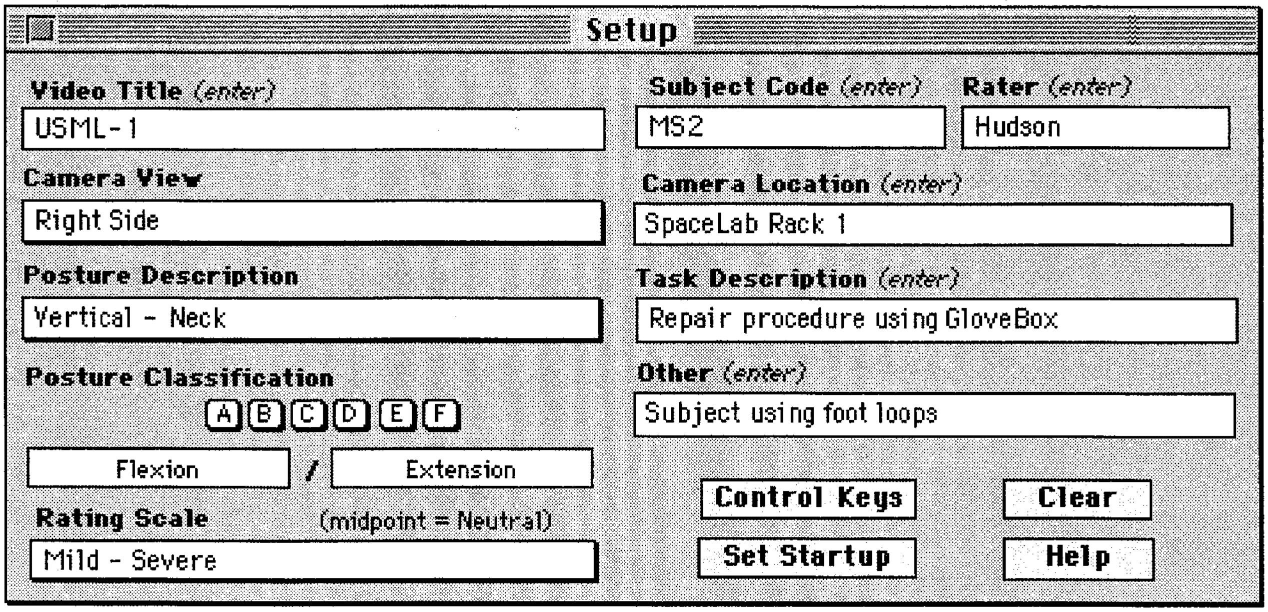

Figure A-3. The Video Analysis Tool (VAT) setup screen.

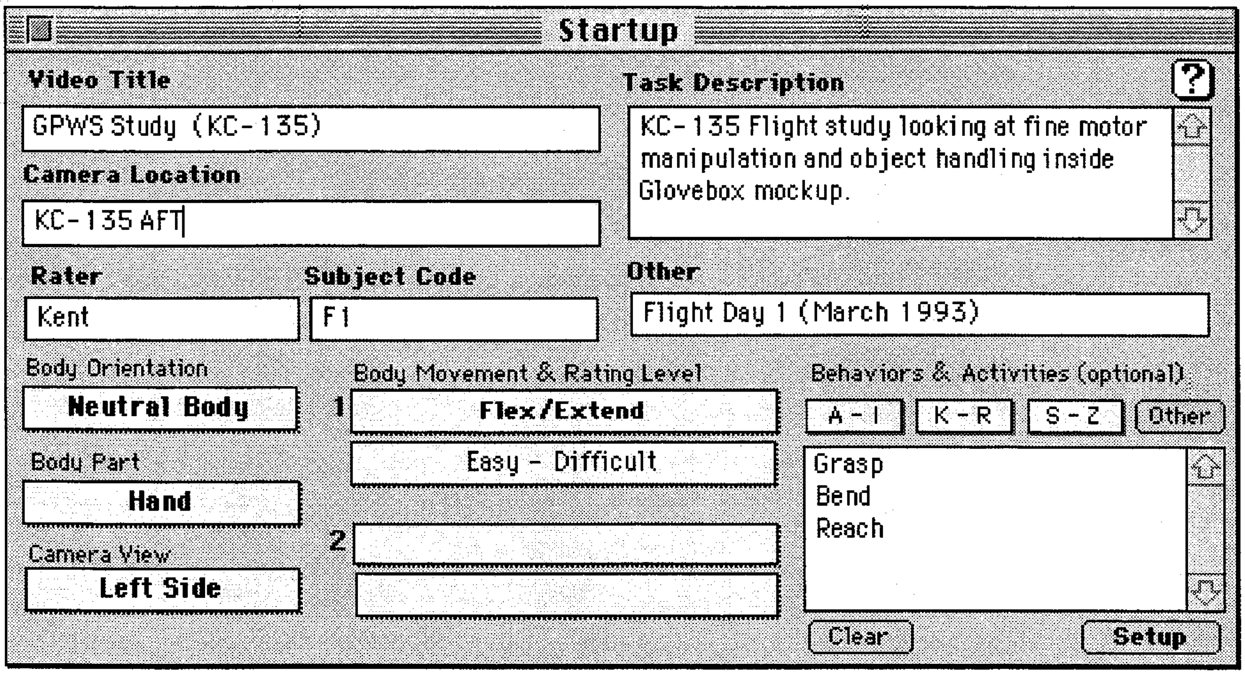

Figure A-4a. The Posture Video Analysis Tool (PVAT) - first iteration - setup screen.

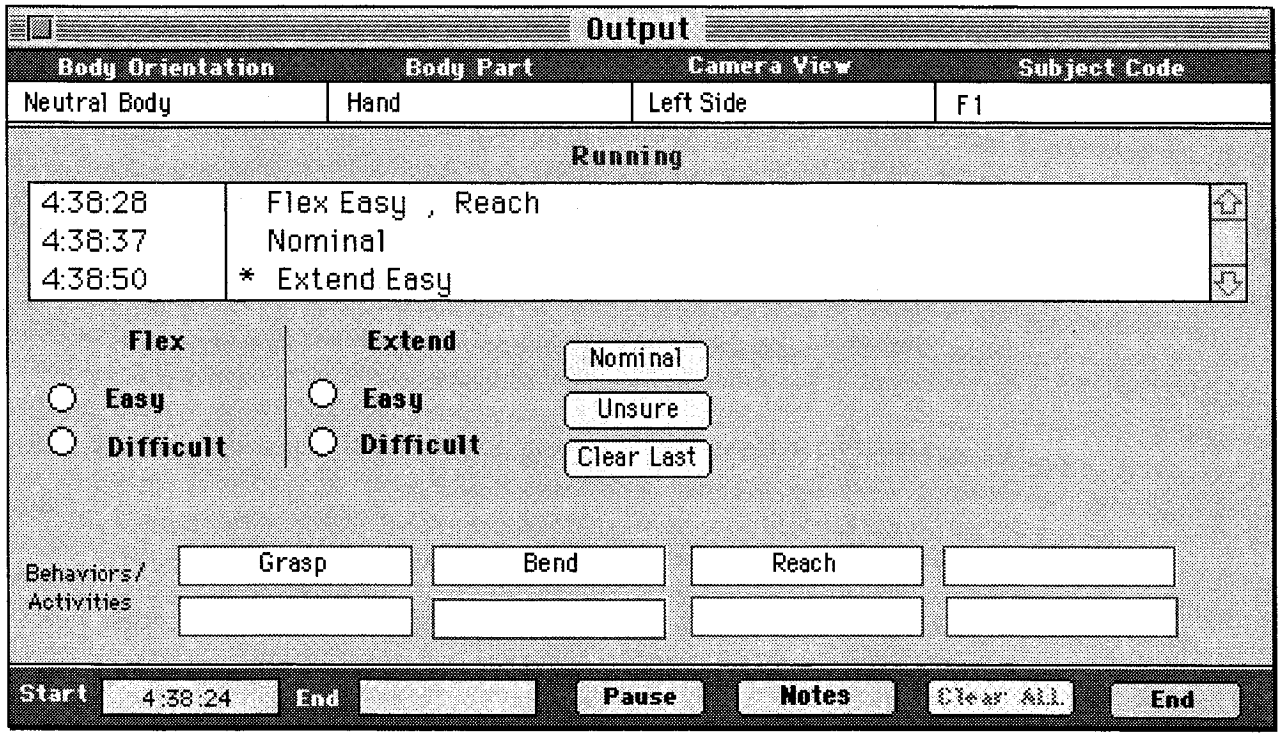

Figure A-4b. The Posture Video Analysis Tool (PVAT) - first iteration - analysis screen.

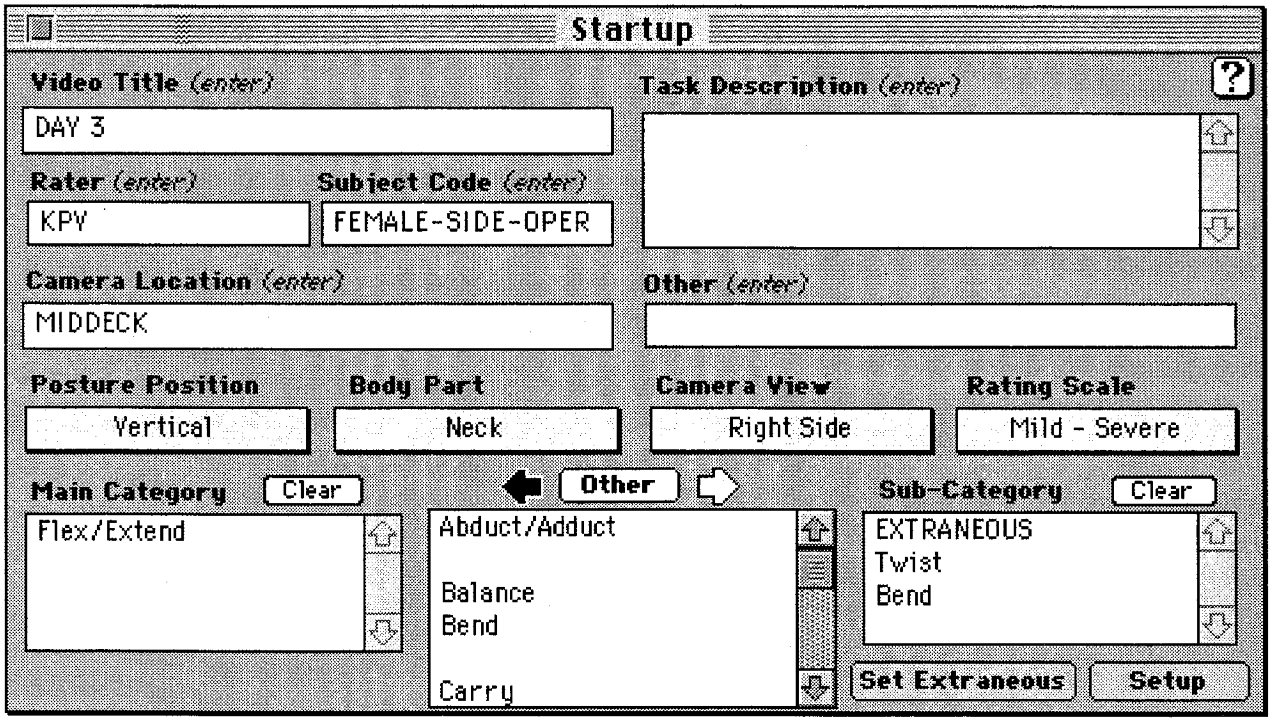

Figure A-5a. Setup screen of PVAT's second iteration.

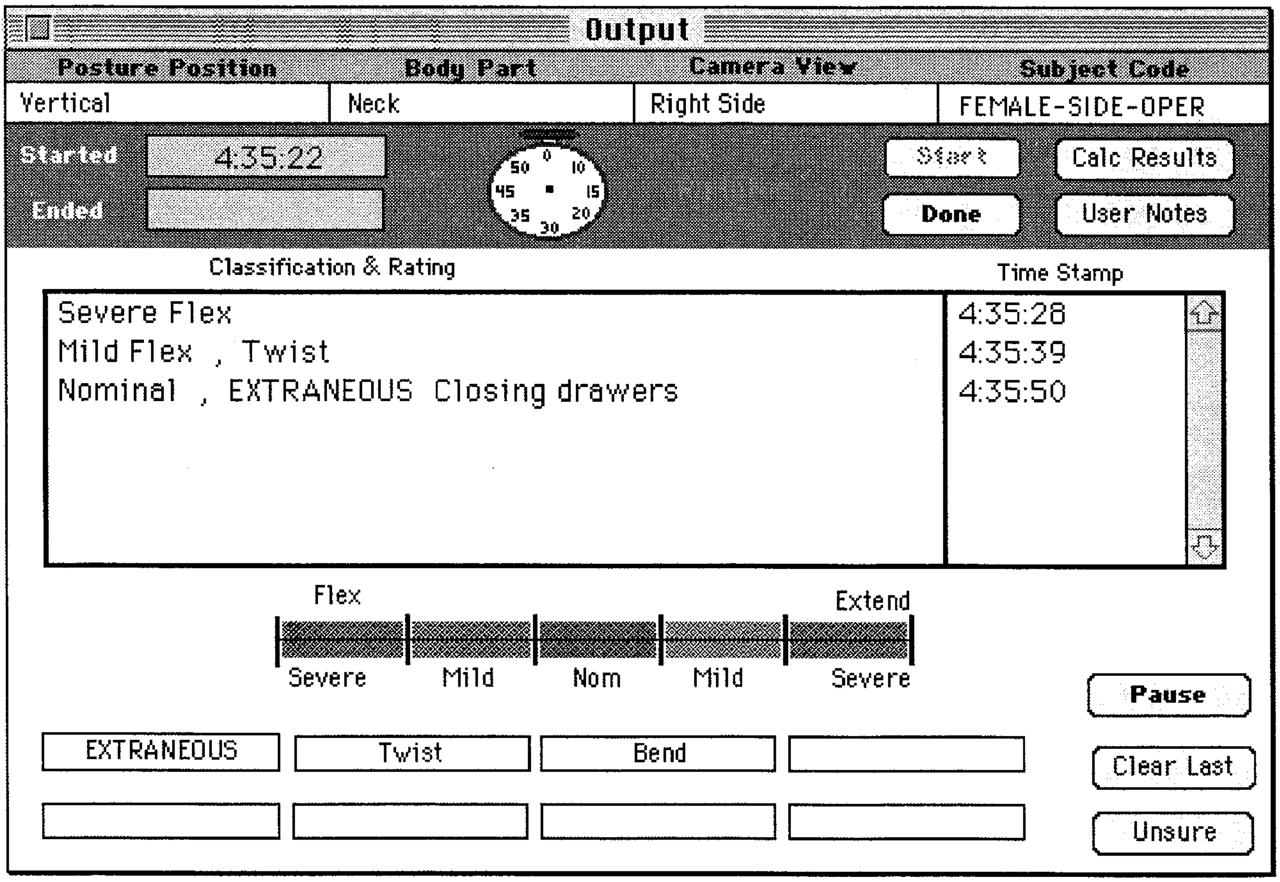

Figure A-5b. Analysis screen of PVAT's second iteration.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1996	NASA Technical Paper

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
Evolution of the Posture Video Analysis Tool* (PVAT)	
6. AUTHOR(S) Andrea H. Berman; Mihriban Whitmore	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Lyndon B. Johnson Space Center Lockheed Martin Engineering & Science Services Houston, Texas 77058	8. PERFORMING ORGANIZATION REPORT NUMBERS S-818
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, D. C. 20546-0001	10. SPONSORING/MONITORING AGENCY REPORT NUMBER TP-3657

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Unclassified/Unlimited Available from the NASA Center for AeroSpace Information (CASI) 800 Elkridge Landing Road Linthicum Heights, MD 21090-2934 (301) 621-0390 Subject Category: 54	

13. ABSTRACT *(Maximum 200 words)*

The Posture Video Analysis Tool* (PVAT) has been developed by the Human Factors and Ergonomics Laboratory (HFEL) engineers at the NASA Johnson Space Center in response to the need for a low cost, reliable method of collecting postural data from nonscientific mission video footage. The PVAT is an interactive Macintosh menu and button driven SuperCard* prototype consisting of a setup and an analysis screen. Since its creation, PVAT has undergone a series of usability evaluations. The testing accomplished thus far has assisted the PVAT designers in improving the interface with both subtle and sweeping changes. The results of these iterative evaluations demonstrated that the PVAT is a promising initial step in identifying and quantifying "limiting microgravity postures" and related workstation design concerns. Furthermore, it is also anticipated that the PVAT will be applicable in a host of nonaerospace industries with little or no modification. If funding is available, further evaluations will be conducted to refine its graphical user interface and demonstrate its industrial applications.

*Trademark

14. SUBJECT TERMS	15. NUMBER OF PAGES
human factors engineering; man-computer interface; posture	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited